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(21) Patentansökningsnummer 0202247-3  
Patent application number

(86) Ingivningsdatum 2002-07-18  
Date of filing

Stockholm, 2003-06-24

För Patent- och registreringsverket  
For the Patent- and Registration Office

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Ansökningsnr

Vår referens

SE-2028196

JETTING DEVICE AND METHOD AT A JETTING DEVICETechnical field of the invention

The present invention generally relates to a method and a device for jetting droplets of viscous medium onto a substrate.

Technical background and prior art

Devices and methods are known in the art for jetting droplets of viscous medium, e.g. solder paste or glue, onto a substrate, e.g. an electronic circuit board, thus forming deposits on the substrate prior to mounting components thereon. Such a jetting device generally comprises an nozzle space for containing a small volume of the viscous medium prior to the jetting thereof, a jetting nozzle communicating with the nozzle space, impacting means for impacting and jetting the viscous medium from the nozzle space through the jetting nozzle in the form of droplets, and feeding means for feeding the medium into the nozzle space.

Since the production speed is an essential factor in the manufacturing of electronic circuit boards, the application of viscous medium is preferably performed "on the fly", i.e. without stopping for each location on the substrate where viscous medium is to be deposited.

When applying solder paste or the like on a substrate, such as a circuit board, it has long been a requirement to have different sizes or areas for deposits on different locations of the substrate. When jetting is used, one solution is to apply several drops on top of each other, thus forming a larger deposit. It has also been suggested to vary the volume of the jetted droplet, thereby varying the size of the resulting deposit, by controlling the impact on the viscous medium.

Summary of the invention

An object of the present invention is to provide an alternative solution to the problem of varying the size 5 of jetted deposits on a substrate.

This and other objects are achieved according to the present invention by providing a method and a device having the features defined in the independent claims. Preferred embodiments are defined in the dependent claims.

For the purposes of this application, it is to be 10 noted that the term "viscous medium" should be interpreted as solder paste, flux, adhesive, conductive adhesive, or any other kind of medium used for fastening components on a substrate, conductive ink, resistive paste, 15 or the like; that the term "deposit" refers to a connected amount of viscous medium applied at a position on a substrate as a result of one or more jetted droplets; that the term "deposit size" mainly refers to the area on the substrate that a deposit will cover, but also that an 20 increase in the droplet volume generally results in an increase also in the deposit height; and that the term "substrate" should be interpreted as a printed circuit board (PCB), a substrate for ball grid arrays (BGA), chip scale packages (CSP), quad flat packages (QFP), wafers, 25 flip-chips, or the like.

It is also to be noted that the term "jetting" 30 should be interpreted as a non-contact dispensing process that utilizes a fluid jet to form and shoot droplets of a viscous medium from a jet nozzle onto a substrate, as compared to a contact dispensing process, such as "fluid wetting".

Thus, the invention is based on the advantageous idea of varying the volume of a droplet to be jetted by regulating the amount of viscous medium that is fed into 35 a nozzle space, or other suitable chamber, for subsequent jetting of viscous medium droplets therefrom. Then, it has been found that viscous medium droplets of varying

volume can be jetted without any adjustment or regulation of the impacting means or operation being required. Even when having the same impacting means acting in the same manner, i.e. with the same length, acceleration and  
5 velocity of the impacting stroke, the volume of jetted droplets may be varied. Thus, by regulating the amount of viscous medium present in the nozzle space when the viscous medium is impacted by the impacting means, the volume of the droplet and, hence, the desired deposit  
10 size can be selected with high precision.

The present invention presents a number of advantages in relation to the existing solutions of varying the size of deposits provided through jetting. Firstly, as compared to the solution of jetting several droplets  
15 onto the same location on the substrate, only one droplet has to be jetted for each deposit. Thus, the jetting can be performed "on the fly", i.e. without stopping for jetting additional droplets to the same location. Alternatively,  
20 the jetting device does not have to pass over the intended deposit location more than once for each droplet.

Furthermore, when jetting multiple droplets at the same location, there will have to be a compromise between small droplets, that will provide good flexibility in  
25 terms of volume alternatives, or large droplets, which will require a lesser number of droplets for very large deposits. Thus, using the present invention for applying viscous medium onto a substrate, a greater flexibility of droplet volume can be achieved and the time required for  
30 the viscous medium application can be significantly reduced, and, thus, the overall production speed can be increased.

Secondly, in comparison with the solution of controlling the impact on the viscous medium. According to  
35 the suggested solutions, this is performed by adapting the depth, i.e. the length of stroke, of the impact provided by impacting means on the viscous medium. How-

ever, variations in the length of stroke also has effects on the exit velocity of the jetted droplets, i.e. the velocity a droplet has when it leaves the nozzle outlet. Thus, a change in the length of stroke in order to 5 achieve a change in the droplet volume, will significantly change the exit velocity of the jetted droplet. In fact, studies have shown that the effects on the exit velocity is greater than the effects on the droplet volume.

10 When jetting "on the fly" there is relative movement between the jetting device and the substrate at the actual instant when a droplet is jetted. Then, the position that the jetting device has when the droplet is jetted must be carefully calculated, in relation to the 15 relative speed between the nozzle and the substrate, the height between the nozzle and the substrate, i.e. the flight distance in the jetting direction, and the jetting or exit velocity, such that the resulting deposit ends up at the correct location on the substrate. As regards the 20 jetting velocity, if it is too high, the droplet will split into a plurality of smaller droplets when hitting the board, and if the velocity is too low, the accuracy of the positioning will be decreased.

Thus, a close control of the exit velocity is of 25 significant importance in order for the correct jetting instant or position to be precisely calculated. As a consequence thereof, significant variations in the exit velocity has a detrimental effect on the quality of the jetting result. If the relative movement between the 30 substrate and the jetting device is slowed down, then the effects of exit velocity variations may be reduced. However, this would of course increase the time required for the application of viscous medium. Thus, the present invention provides for jetting of viscous medium with an 35 improved quality of the jetting result and/or an increased production speed as compared to known solutions of controlling the impact on the viscous medium.

According to the present invention, the jetting device comprises feeding means for feeding viscous medium towards a jetting nozzle, from where droplets of viscous medium may be jetted. The jetting device further comprises impacting means for impacting viscous medium fed by the feeding means, such that droplets of viscous medium are jetted through the nozzle towards a substrate. Following an impact on the viscous medium, the impacting means is preferably immediately returned to a position ready for impact, so as to not interfere with the feeding of viscous medium for the droplet to be subsequently jetted.

The jetting nozzle, in turn, comprises a nozzle outlet through which the droplets are jetted towards the substrate, said nozzle outlet being located at one end of the nozzle. The end portion of the nozzle where the nozzle outlet is located will below be referred to as the lower portion of the nozzle, even though the device of course may be oriented for jetting droplets in any direction, not only downwards. Furthermore, the nozzle has surrounding inner walls defining a nozzle space, which is in open communication with the nozzle outlet. The portion of the nozzle opposite the nozzle outlet, referred to below as the upper portion of the nozzle, is arranged for receiving viscous medium supplied by the feeding means.

According to the invention, the nozzle space is filled with viscous medium to a varying degree prior to the jetting of individual droplets, the degree being adjusted in dependence on the volume of the droplet to be jetted, which in turn is dependent on the desired size of the deposit. For the largest droplet volume, the entire nozzle space is filled with viscous medium.

Preferably, the filling of the nozzle space is performed from the upper portion towards the nozzle outlet. In other words, when the nozzle space is partially filled with viscous medium, the lower portion of the nozzle

space is free of viscous medium, see the detailed description below with reference to the figures. Thus, an essentially void free amount of viscous medium extends from the nozzle outlet to and through the feeding means.

5 Moreover, the nozzle is preferably configured such that the nozzle space, or at least a substantial portion thereof, is tapered in the direction towards the nozzle outlet, said taper even more preferably having a conical, or rather a frusto-conical, configuration.

10 According to preferred embodiments of the invention, the feeding rate, i.e. the rate with which the viscous medium is supplied to the jetting nozzle by the feeding means, is adjustable. Thereby, the time required for feeding the appropriate amount of viscous medium into the  
15 nozzle space for jetting of a droplet of a desired volume can be regulated. This means that the time required for feeding the appropriate amount into the nozzle space can be maintained at an essentially constant level, irrespec-  
tive of the amount and, hence, the desired droplet  
20 volume, and the corresponding jetting sequence can be maintained at a constant frequency, if desired. Furthermore, the feeding rate and, hence, the time required for feeding the appropriate amount, can be adjusted to accommodate different jetting frequencies.

25 According to an exemplary embodiment, varying the controlled amount of viscous medium that is fed to the nozzle space for the jetting of a droplet is obtained by varying the duration of the feeding action, i.e. the time period during which the feeding means feeds viscous  
30 medium into the nozzle space. Then, the feeding rate may be kept essentially constant.

It should be noted that the feeding rate affects the feeding pressure, i.e. the pressure experienced by the viscous medium that urges the viscous medium forward in  
35 the feeding direction. Thus, the feeding pressure regu-  
lates the rate at which the viscous medium flows into the nozzle space. When jetting shall be provided at a higher

frequency for a particular droplet volume, the time required for feeding the appropriate amount into the nozzle space has to be reduced. Thus, a desired increase in jetting frequency without changing the droplet volume 5 requires an increase in the feeding pressure, and vice versa. Correspondingly, a desired increase in the droplet volume without changing the jetting frequency requires an increase in the feeding pressure.

Also, according to preferred embodiments of the 10 invention, the jetting device further comprises a jetting chamber, located between the jetting nozzle and the feeding means and in open communication with the upper portion of the nozzle space. Thus, when the feeding means supplies viscous medium to the nozzle space, the viscous 15 medium is supplied via the jetting chamber. According to this embodiment, the actual jetting is provided by having an end surface of the impacting means impacting the viscous medium in the jetting chamber. As a result, the impacting effect propagates through the viscous medium in 20 the jetting chamber, and brings viscous medium contained in the nozzle space to be jetted through the nozzle outlet onto the substrate. Then, it has been found that the volume of the jetted viscous medium droplet essentially corresponds to the volume of viscous medium contained in 25 the nozzle space. Thus, by regulating the amount of viscous medium present in the nozzle space when the viscous medium is impacted by the impacting means, the volume of the droplet and, hence the desired deposit size can be selected with high precision.

30 One problem frequently encountered within the art is to provide a reproducibly accurate droplet size. In particular, the first droplet or droplets jetted following a pause in a jetting sequence tend(s) to have a different size as compared to the following droplets or the 35 intended droplet size. The duration of a pause that will have a negative impact on the accuracy of the volume of the subsequent first droplet(s) is dependent on the

above-mentioned feeding pressure. Thus, if the feeding pressure prior to and following the pause is low, the time required for a pause to have such negative effects on the droplet volume accuracy that it needs to be compensated for is longer than if said feeding pressure is high.

According to preferred embodiments of the invention, the above-stated problem is solved by providing a feeding pressure prior to the jetting of the first drop following a pause that corresponds to the feeding pressure at the jetting of successive droplets within a jetting sequence, i.e. so late in the jetting sequence that the problems of the first droplet(s) are not encountered. According to these embodiments, the feeding means is activated during said pause such that viscous medium is fed into the nozzle space and fills the nozzle space entirely. When the nozzle space has been filled, any excess viscous medium, i.e. viscous medium fed into the nozzle space in excess of what said space may accommodate, flows out of the nozzle outlet. Prior to the feeding into the nozzle space of the amount of viscous medium required for jetting a droplet of a desired volume, the amount of viscous medium present in the nozzle space is reduced by a preset amount, such that the amount of viscous medium present in the nozzle space after said reduction is at a predetermined or preset degree.

Preferably, the time when the feeding means is activated for filling the nozzle space during a pause, i.e. the time period prior to initiating the jetting of the first droplet after the pause, is carefully selected so as to ensure filling of the entire nozzle space, while simultaneously avoiding excessive flow of viscous medium through the nozzle outlet. Said time period is preferably calculated in relation to the chosen feeding rate and corresponding feeding pressure.

According to a preferred embodiment of the invention, any excess viscous medium that may flow out of

the nozzle outlet when filling the nozzle space during said pause is removed. This embodiment will be further described below.

For the embodiments where a jetting chamber is provided between the nozzle and the feeding means, said reduction is provided by increasing or expanding the volume of the jetting chamber. Thus, due to the open communication with the jetting chamber and the fact that the jetting chamber and nozzle space is entirely filled with viscous medium, i.e. in an essentially void-free condition, an amount of viscous medium corresponding to the expansion is withdrawn or retracted into the jetting chamber. Thus, the volume present in the nozzle space immediately following said expansion may be accurately predicted or predetermined. Then, jetting is resumed by feeding the appropriate amount of viscous medium into the nozzle space and impacting viscous medium in the manner described above.

Preferably, a wall of the jetting chamber located opposite the jetting nozzle is constituted by an impact end surface of the impacting means, said end surface preferably being circular. Thus, the impact end surface of the impacting means defines one wall of the jetting chamber. In connection with the filling of the nozzle space during a pause and in preparation for the jetting of the first droplet(s) following the pause, the impact end surface is brought or has been brought into an idle position. This can be performed by rapidly bringing the end surface into the idle position immediately following the jetting of the last droplet prior to the pause, i.e. when the nozzle space preferably is substantially free of viscous medium. According to another example, the end surface is brought to an idle position slowly so as to avoid any inadvertent jetting of viscous medium that might be present in the nozzle space.

Following the movement of the end surface into an idle position, the expansion of the jetting chamber may

be provided by moving the end surface of the impacting means in a direction away from the nozzle from said idle position into a position ready for impacting. Thus, the expansion of the jetting chamber, and the resulting retraction of viscous medium from the nozzle space, may be provided without the need for additional means or elements for expanding the jetting chamber.

What has been explained above about bringing the impact means into an idle position thus includes the alternative of moving the impacting means into the idle position immediately after jetting the last droplet prior to the pause, i.e. so that the impacting means will have no time to retract to the position ready for impacting, and the alternative of first moving the impacting means to the position where it is ready to impact, then moving it into the idle position.

Another variable affecting the accuracy of the jetting and, hence, the quality of the viscous medium provided on substrate, is the velocity with which the droplets are jetted onto the substrate. Studies have shown that when amending the droplet volume, the exit velocity of the jetted droplet is affected. According to preferred embodiments of the present invention, the exit velocity of the jetted droplet is controlled by amending the impacting characteristics of the impacting means. Preferably, this is provided by regulating the impact velocity or impact force of the impacting means such that a predetermined exit velocity can be maintained irrespective of the volume of the droplet to be jetted. Then, it has been found that a droplet of smaller volume has a lower exit velocity as compared to a droplet of larger volume. Thus, the impact velocity or impact force is preferably increased for a droplet of smaller volume and decreased for a droplet of larger volume.

As evident to a person skilled in the art, there are a number of choices of different impacting means that may be used to accomplish jetting of droplets, such as a

magnetostrictive, electrostrictive or electromagnetic actuator, or an actuator having shape memory alloy properties. However, according to preferred embodiments of the invention, a piezoelectric actuator is used. Then, 5 the above mentioned regulation of the impact velocity or force is accomplished by regulating the voltage applied to the piezoelectric actuator.

Even though a number of different means for feeding viscous medium are conceivable within the scope of this 10 invention, such as pneumatic means, gear-driven pumps, piston pumps, etc., according to preferred embodiments of the invention, said feeding means is provided in the form of a rotatable feed screw. Such a feed screw for feeding viscous medium to a jetting chamber or to a jetting 15 nozzle in a jetting device is disclosed in WO 99/64167, which is incorporated herein by reference. A further example is disclosed in the co-pending Swedish patent application SE 0104210-5, which also is incorporated herein by reference.

20 The use of such a rotatable feed screw makes it possible to control the feeding of viscous medium to the nozzle space in an advantageously accurate, rapid and simple manner. Rotational movement of the rotatable feed screw will immediately affect the behavior of the viscous 25 medium at the output end of the rotatable feed screw near the nozzle space, as compared to the use of a pressure device for supplying viscous medium to a jetting nozzle, which will cause an effect at the jetting nozzle only after a certain time delay, which is given by the time it 30 takes for a pressure wave to travel through the medium from the pressure device to the nozzle. Furthermore, by placing the feeding outlet of the feed screw in close proximity to the jetting nozzle or jetting chamber, the volume in which the compressibility of the viscous medium 35 may have a negative effect on the accuracy of the feeding control is considerably decreased, thus limiting the negative effects concerning the difficulty to accurately

control the feeding operation caused by said compressibility.

According to further preferred embodiments of the invention, there is provided means for removing viscous medium from the nozzle outlet. Thereby, viscous medium residue that might have become attached to the nozzle outlet is removed. Thus, the problem of viscous medium residue interfering with the jetted droplet so as to alter the volume of the droplet, e.g. a volume of viscous medium residue situated at the nozzle outlet may loosen from the surface and instead adhere to and be incorporated into the jetted droplet, is effectively avoided. Furthermore, there is no risk of viscous medium residue causing spattering of viscous medium when a jetted droplet "collides" with the residue. For the embodiment where excess viscous medium may flow out of the nozzle outlet when filling the nozzle space during a pause, the excess viscous medium is also removed from the nozzle outlet by the provided removing means.

Preferably, according to an embodiment of the present invention, a gaseous flow is provided past the nozzle outlet, the magnitude and the velocity of the gaseous flow being sufficient for transporting viscous medium away from the area at the nozzle outlet with the gaseous flow. The provision of such a gaseous flow at a jetting device is disclosed in co-pending International patent application PCT/SE02/00807, which is incorporated herein by reference.

The provision of a gaseous flow during the jetting of droplets provides a number of advantages. First, any viscous medium residue that has become attached to the nozzle outlet surfaces following the jetting of a droplet is immediately transported away from the vicinity of the nozzle outlet. Second, the gaseous flow can pick up and transport away from the nozzle outlet minute quantities of viscous medium that have broken off from the droplet or jet and that would otherwise adhere to the surfaces of

the nozzle outlet as residue. Thus, the build-up or accumulation of viscous medium residue at the nozzle outlet to an adverse amount is prevented. Furthermore, the gaseous flow will also transport the above mentioned excess viscous medium away from the nozzle outlet.

5 Preferably, the gaseous flow is generated by suction generating means, i.e. in the form of a vacuum ejector or any other suitable type of suction generator. Said suction generating means then being provided downstream of 10 the area surrounding the nozzle outlet, as seen in the direction of the gaseous flow.

Furthermore, according to exemplifying embodiments, the jetting device is provided with a wall, the wall being spaced apart from the nozzle outlet and located 15 downstream of the nozzle outlet seen in the direction of the jetted droplets at the nozzle outlet. Said wall may, as an example, constitute part of a nozzle support, but can be provided without having any supporting function for the nozzle. Between the wall and the nozzle outlet, 20 there is formed a space acting as a channel or guide for the gaseous flow at and past the nozzle outlet. Since said wall is located in the jetting path, the wall is provided with an opening or orifice, concentric with the nozzle outlet. The jetted droplets are thereby permitted 25 to pass through the wall via the orifice. Preferably, the orifice of the wall also functions as an inlet for the gaseous flow towards the nozzle outlet.

According to exemplifying embodiments of the invention, the jetting device is comprised in a jetting assembly, which is releasably mountable in a machine that uses 30 the assembly for providing a substrate with viscous medium deposits. Such an assembly cassette is disclosed in WO 00/61297, which is incorporated herein by reference.

35 By being releasably mountable in the machine, the assembly may be used as a separate unit that is easily exchangeable and contains the viscous medium. Apart from

the obvious utilization of exchanging the assembly when the viscous medium runs out, the assembly can further be dimensioned to be particularly suitable for applying droplets within a certain volume range. It should be noted, that in order to provide an increase in the deposit diameter by a factor of 2, the increase in the droplet volume will probably have to be increased by a factor of between 4 to 8 depending on how much the deposit height will be affected by the volume increase.

Thus, for instance, if viscous medium deposits varying in size from a diameter of 0,25 mm up to 0,8 mm are to be provided on a substrate, one assembly may be provided for supplying the substrate with deposits having diameters in the range of 0,25-0,5 mm, and an other assembly may be provided for deposits having diameters in the range of 0,4-0,8 mm.

Further objects and advantages of the present invention will be discussed below by means of exemplifying embodiments.

20

#### Brief description of the drawings

Preferred embodiments of the invention will now be described in greater detail with reference to the accompanying drawings, in which

25 Fig. 1 is a perspective view showing the general outline of a machine for application of solder paste comprising a jetting device according to the present invention;

Fig. 2 is a schematic view from above of an embodiment of a docking device and a jetting assembly of the present invention;

30 Fig. 3 is a schematic view showing the underside of the assembly shown in Fig. 2;

Fig. 4 is a schematic view showing a cut away portion of the assembly shown in Fig. 2;

35 Fig. 5 is a schematic view of an embodiment of a waste container according to the present invention;

Fig. 6a-6c illustrate different degrees of solder paste filling according to an embodiment of the method of the present invention;

5 Fig. 7a and 7b illustrate operation principles according to an embodiment of the method of the present invention;

Fig. 8a and 8b are graphs illustrating drive signals according to an embodiment of the method of the present invention; and

10 Fig. 9 is a schematic view of an embodiment of a nozzle according to the present invention.

Description of preferred embodiments

Fig. 1 illustrates an embodiment of a machine 1 for providing a substrate 2 with deposits by jetting droplets of a viscous medium onto the substrate 2, in accordance with the present invention. Let us for simplicity assume that the viscous medium is solder paste, which is one alternative as defined above. For the same reason, the 15 substrate 2 will be referred to as an electric circuit board and the gas of the gaseous flow discussed above will be referred to as air. In this embodiment the machine 1 is of a type comprising an X-beam 3 and an X-wagon 4 connected with the X-beam 3 via an X-rail 16 and reciprocatingly movable along the X-rail 16. The X-beam, 20 in turn, is reciprocatingly movably connected with a Y-rail 17, thereby being movable perpendicularly to the X-rail 16. The Y-rail 17 is rigidly mounted in the machine 1. Generally, the movements are driven by linear motors 25 (not shown).

Further, the machine 1 comprises a conveyor 18 for carrying the substrate 2 through the machine 1, and a locking device 19 for locking the substrate 2 when jetting is to take place.

35 A docking device 8 is connected to the X-wagon 4 for enabling releasable mounting of an assembly 5 at the docking device 8. The assembly 5 is arranged for dispens-

ing droplets of solder paste, i.e. jetting, which impact and form deposits on the board 2.

The machine 1 also comprises an exchange assembly support 20, supporting further assemblies 22, which may 5 be substituted for the assembly 5 currently carried by the docking device 8.

Furthermore, the machine 1 comprises a machine vision device 7, which in this embodiment is a camera. The camera 7 is used for determining the position and 10 rotation of the substrate 2 and for checking the result of the dispensing process by viewing the deposits.

Additionally, the jetting machine 1 comprises a suction generating means, here in the form of a vacuum ejector 6, arranged on the X-wagon 4, and a source of compressed air (not shown). The vacuum ejector 6, as well 15 as the source of compressed air, is in communication with the docking device 8 via air conduit interface means which are connectable to complementary air conduit interface means, in this embodiment indicated as input nipples 9, see Fig. 2, of the docking device 8.

As understood by those skilled in the art, the jetting machine comprises a control unit (not explicitly shown) for executing software running the machine.

Briefly, the jetting machine works as follows. The 25 board 2 is fed into the jetting machine 1 by means of the conveyor 18, upon which the board 2 is placed. When the board 2 is in the correct position under the X-wagon 4, the board 2 is fixed with the aid of the locking device 19. By means of the camera 7, fiducial markers are 30 located, which markers are prearranged on the surface of the board 2 and used to determine the precise position thereof. Then, by moving the X-wagon over the board 2 in a predetermined (pre-programmed) pattern and operating the jetting assembly 5 at predetermined locations, solder 35 paste is applied on the board 2 at the desired locations.

With reference to Figs 2-3, an embodiment of the jetting assembly 5, in accordance with the present inven-

- tion, will now be described in more detail. The jetting assembly comprises an assembly holder 11 having holding means for connecting the jetting assembly 5 to an assembly support 10 of the docking device, see Fig. 2.
- 5 Further, in this embodiment the jetting assembly 5 comprises a supply container 12 providing a supply of solder paste, and an assembly housing 15. The jetting assembly 5 is connected to the vacuum ejector 6 and the source of pressurised air via pneumatic interface means comprising 10 inlets 42, positioned to interface in airtight engagement with complementary pneumatic interface means comprising outlets 41, of the docking device 10. The outlets 41, in turn, are connected, via internal conduits of the docking device 8, to the inlet nipples 9 described above.
- 15 With reference now to Fig. 4, the contents and function of the parts enclosed in the assembly housing 15 will be explained in greater detail. As can be seen in Fig. 4, the jetting assembly 5 comprises an impacting means, which in this embodiment constitutes a piezoelectric actuator 21 comprising a number of thin, piezoelectric elements stacked together to form an actuator part 21a. One, upper, end of the actuator part 21a is rigidly connected to the assembly housing 15. The assembly further comprises a bushing 25 rigidly connected to the 20 assembly housing 15. The impacting means further comprises a plunger 21b, which is rigidly connected to the other, lower, end of the actuator part 21a. The plunger 21b is axially movable while slidably extending through a bore in the bushing 25. Cup springs 24 are provided to 25 resiliently balance the plunger 21b against the assembly housing 15, and for providing a preload for the actuator part 21a. An eject control unit (not shown) applies a drive voltage intermittently to the piezoelectric actuator 21, thereby causing an intermittent extension 30 thereof, and hence a reciprocating movement of the plunger 21b with respect to the assembly housing 15, in accordance with solder pattern printing data.

Further, the assembly comprises an essentially plate shaped jetting nozzle 26 operatively directed against the board 2, onto which small droplets of solder paste are to be jetted. In the jetting nozzle 26, there is provided a 5 through hole defined by a first frusto-conical portion 91, see Fig. 9, extending from a top surface 92 of the nozzle 26 and downwards through most of the thickness of the nozzle 26, and a second frusto-conical portion 93 extending upwards from a bottom surface 94 of the nozzle 10 26 to the plane of the top of the first frusto-conical portion 91. Thus, the tops of the frusto-conical portions 91, 93 are directed towards each other. However, the diameter of the top of the second frusto-conical portion 93 is larger than the diameter of the top of the first 15 frusto-conical portion, and therefore they are connected by a ring portion 95, which is in parallel with the top and bottom surfaces 92, 94 of the nozzle 26. The top of the first frusto-conical portion 91 defines a nozzle outlet 27 through which the droplets are jetted towards 20 the board 2. Further a nozzle space 28 is defined by the first frusto-conical portion 91, i.e. by the inner walls thereof. Thus, the nozzle outlet 27 is located at one end, a lower portion 95, see Fig. 9, of the nozzle 26. The other end, an upper portion 96, of the nozzle 26, 25 i.e. the base of the first frusto-conical portion 91, is arranged for receiving viscous medium, which is forced through the nozzle space 28 and out of the nozzle outlet 27.

The plunger 21b comprises a piston portion which is 30 slidably and axially movably extending through a piston bore 35, an impact end surface 38 of said piston portion of the plunger 21b being arranged close to said nozzle 26.

A jetting chamber 37 is defined by the end surface 38 of said plunger 21b, the cylindrical inner wall of the bushing 25, the upper surface 92 of the nozzle 26, which upper surface 92 is positioned opposite to the impact end

surface 38, and the upper end 96 of the nozzle space 28. Thus, the jetting chamber 37 is in open communication with the upper portion of the nozzle space 28. Axial movement of the plunger 21b towards the nozzle 26, said 5 movement being caused by the intermittent extension of the piezoelectric actuator 21, will cause a rapid decrease in the volume of the jetting chamber 37, and thus a rapid pressurisation and jetting through the nozzle outlet 27, of any solder paste contained in the 10 nozzle space 28.

Solder paste is supplied to the jetting chamber 37 from the supply container 12, see Fig. 2, via a feeding means 23. The feeding means comprises an electric motor (not shown) having a motor shaft 29 partly provided in a 15 tubular bore 30, which extends through the assembly housing 15 to an outlet port 36. The outlet port 36 communicates with the jetting chamber 37 via a tubular bore 31, provided in the housing 15, a radial bore 39, extending radially of the bushing 25 through the wall thereof, and 20 an axial groove 40, made in the inner surface of the bushing 25 and extending from the inner end of the radial bore 39 down to the jetting chamber 37.

An end portion of the motor shaft 29 forms a 25 rotatable feed screw 32 which is provided in, and coaxial with, the tubular bore 30, and which ends at the outlet port 36. An essential portion of the rotatable feed screw 32 is surrounded by a tube 33, made of an elastomer or the like, arranged coaxially therewith in the tubular bore 30, the threads of the rotatable feed screw 32 30 making sliding contact with the innermost surface of the tube 33. An alternative to the tube is an array of resilient, elastomeric O-rings.

The pressurised air obtained from the above-mentioned source of pressurised air (not shown) is arranged 35 to apply a pressure on the solder paste contained in the supply container 12, thereby feeding said solder paste to an inlet port 34, provided at the beginning, or upper end

of, the threads of the feed screw 32. An electronic control signal provided by a supply control unit (not shown) to the motor causes the motor shaft 29, and thus the rotatable feed screw 32, to rotate a desired angle, 5 or at a desired rotational speed. Solder paste captured between the threads of the rotatable feed screw 32 and the inner surface of the o-rings 33 are then made to travel from the inlet port 34 to the nozzle space 28 via the outlet port 36, the tubular bore 31, the radial bore 10 39, the groove 40, and the jetting chamber 37, in accordance with the rotational movement of the motor shaft 29.

As shown in Figs 3 and 4, a plate, or wall, 14 is arranged below, or downstream, of the nozzle outlet 27, as seen in the jetting direction. The plate 14 is 15 provided with a through hole 13, through which the jetted droplets may pass without being hindered or negatively affected by the plate 14. Consequently, the hole 13 is concentric with the nozzle outlet 27. The plate 14 is spaced apart from the nozzle outlet 27. Between the plate 20 14 and the nozzle outlet 27, there is formed an air flow chamber 44, which is a space acting as a channel or guide that is connected with the vacuum ejector 6 for generating an air flow, illustrated, for example, by the arrows 25 of Fig. 9, at and past the nozzle outlet 27. In this embodiment, the air flow chamber 44 is disc shaped. In this embodiment, the hole 13 acts as an inlet for the air flow towards and past the nozzle outlet 27.

An air flow conduit 43 extends between the air flow chamber 44 and a waste container 50, see Fig. 5, which is 30 arranged in the flow path from the air flow chamber 44 and the vacuum ejector 6. The air flow conduit 43 is not visible in Fig. 4 since it extends out of the plane of the paper. The waste container 50 is releasably connected to the jetting assembly 5 and collects fragments of residue solder paste originating from the nozzle outlet 35 27, as will be described in detail below. The waste container 50 is connected to the jetting assembly 5 at

interface means on the jetting assembly 5, via corresponding interface means arranged on said waste container 50. The waste container 50 provides an interface and communication between the jetting assembly 5 and the vacuum ejector 6. Thereby, the negative pressure or vacuum produced by the vacuum ejector 6 is conveyed to the jetting assembly 5, and to the communicating air flow conduit 43 and air flow chamber 44.

The waste container 50 comprises an air conduit 53, which extends from said connecting interface. The air conduit 53 communicates with a collection space 55 over a separating wall 54, the collection space being arranged for collection of solder paste residue removed from the nozzle outlet 27.

At the top of the collection chamber 55, a narrow air conduit 52 leads the air flow from the collection chamber 55 into a filter 56. The filter 56 is of a conventional type and is provided for preventing any fragments of solder paste not collected in the collection chamber 55 from reaching the vacuum ejector 6. The filter 56 is further in communication with an outlet conduit 57.

The waste container 50 is releasably connected to the vacuum ejector 6, which is of a conventional type, for evacuating the waste container 50. The vacuum ejector 6 is connected to the waste container 50 via the air outlet 57, a connector 58 and an air tube 59. Even though the vacuum ejector is illustrated as being separate from the jetting assembly 5 and/or the waste container 50, a number of other placements or combinations of the vacuum ejector 6, the jetting assembly 5, and the waste container 50 are of course conceivable within the scope of the present invention.

In operation, the vacuum ejector 6 evacuates the waste container 50. This evacuation produces an air flow through the waste container as indicated by the arrows in Fig. 5. As a consequence, the air flow conduit 43 and the air flow chamber 44 of the jetting assembly 5 are also

evacuated via the interface. Thus, air is sucked in through the outlet hole 13, which gives rise to a strong air flow in a direction reverse to that of the jetted droplets. This air flow will pass the nozzle outlet 27 and remove any undesired residue of solder paste that may have become adhered to the nozzle outlet, for reasons described above.

According to the present embodiment of the invention, the air flow is provided before, during and after the jetting of each droplet. However, if more appropriate, the air flow could also be provided intermittently. The air flow path is constructed such that, due to the force of the air flow, solder paste fragments removed from the vicinity of the jetting outlet will be carried along into the collection chamber, where they, or at least a majority thereof, due to the gravity force will fall down. Any residue of solder paste that may continue along with the air flow into the narrow conduit 52, will be collected by the filter 56.

The support plate 14 may alternatively comprise one or more additional hole(s). Naturally, the positioning and design of the other hole(s) must be such that a forceful flow of air is provided at or past the nozzle outlet 27.

In order to obtain a well controlled and individually adjusted amount of solder paste in each droplet, the degree of filling of the nozzle space 28 before each jetting is set. Different degrees of filling are shown in Figs 6a-6c, which similarly illustrates an alternative embodiment of the nozzle 60, which still comprises a frusto-conical portion 61 that defines most of the nozzle space 62. However, rather than the second frusto-conical portion 93, there is provided a cylindrical portion 63. The upper end of the cylindrical portion 63 coincides with the top end of the frustum of a cone 61, and the lower end of the cylindrical portion 63 is positioned at the bottom surface 65 of the nozzle 60. In this alterna-

tive embodiment the nozzle outlet 64 is defined by the lower end of the cylindrical portion 63.

From Figs 6a-c it is also evident that the nozzle space 62 is filled from the upper portion thereof towards the nozzle outlet 64. Thus, if the nozzle space 62 is filled to a small extent, as shown in Fig. 6a, a comparatively small droplet is then jetted, while if the nozzle space is fully filled, as in Fig. 6c, a largest possible droplet is jetted.

As shown in Figs 7a and 7b, before jetting a first droplet after a pause, or at start up of the jetting machine, in order to ascertain that the degree of filling of the nozzle space, in these figures denoted 72, will be correct, firstly solder paste is fed, by means of the feed screw 32, to such an extent that it fills the nozzle space 72 completely, as in Fig. 7a. While doing this the solder paste may even be forced out of the nozzle outlet 74. Any excessive solder paste is prevented, due to the suction function obtained by means of an air flow as described above, from falling down onto a board located beneath the nozzle 70. The air flow is schematically indicated by the horizontal arrows in Fig. 7a. It is to be noted that for reasons of simplicity the plate downstream of the nozzle outlet is left out in Figs 7a-b, as well as in Figs 6a-c. Meanwhile, the plunger 21b is held in an idle position. Secondly, the volume of the jetting chamber is increased by retracting the plunger 21b, by means of controlling the actuator part 21a. The plunger 21b is retracted a predetermined distance so as to empty the nozzle space 28/72 to an accurately predetermined extent, as shown in Fig. 7b. In this embodiment the nozzle space 72 is almost totally emptied. Knowing now the current degree of filling of the nozzle space 28/72, the device is ready for impacting. The jetting of the droplet should then follow more or less immediately, in order to assure that there is no time for a substantive change in the condition to occur. The jetting then begins

by feeding solder paste into the nozzle space 28 in accordance with information on what size of droplet that is to be jetted. When the feeding is done the actuator is energized so as to obtain an impacting movement of the 5 plunger 25, which movement decreases the volume of the jetting chamber 37 to such an extent that the amount of solder paste that is present in the nozzle space 28 is jetted onto the board 2. By this method it is possible to jet an accurate and predetermined amount of solder paste 10 already at the first jetting after a period of inactivity that is too long for the conditions of the nozzle to persist from the finish of the preceding jetting of a droplet.

Typically, a series of droplets are jetted consecutively. Accordingly, the stepper motor rotating the feed screw 32 is driven with a signal of a predetermined frequency. An example thereof is shown in Fig. 8a, and more specifically the upper curve thereof, where the pulses of a pulse signal are applied to the stepper 15 motor. For each pulse a known amount of solder paste is fed into the jetting chamber. The lower curve illustrates the control signal that is applied to the actuator. Fig. 20 8a shows the initialisation phase, where the pulse signal is applied to the stepper motor during a time period, here about 20 ms before the first droplet is jetted. More 25 specifically, first the generation of the pulse signal is started, while the plunger 21b is in the idle position. Some 18 ms later, i.e. at the time of 20 ms in the graph, the voltage of the actuator control signal is changed so 30 as to cause a retraction of the plunger 21b in order to withdraw solder paste from the nozzle space 28. Now the initialisation is finished, and the jetting sequence begins. Thus, a number of pulses, at the duration of about 2 ms, as is more clearly shown in Fig. 8b, are 35 applied to the motor before an impacting pulse is applied to the actuator 21a causing a plunger movement towards the nozzle space 28, which causes a droplet to be jetted.

The duration of the impacting pulse is very short, meaning that the plunger 21b is almost immediately returned to the position where it is ready to perform the next jetting. For purposes of simplicity, in this example merely three jetting pulses are illustrated. As can be seen from Fig. 8b, the plunger is moved fastly to the idle position just after the last droplet has been jetted and the plunger has returned to the ready position. It is to be noted that the rotation of the feed screw is stopped at the last jetting, and consequently no further solder paste is fed into the jetting chamber 37, which also means that no solder paste has been fed into the nozzle space 28 after the last jetting, i.e. no solder paste will be accidentally jetted when moving the plunger 21b to the idle position. This is one alternative of placing the device in an idle state.

Still, in accordance with another embodiment of the method according to the present invention, the transition into the idle state is done slowly in order to further ascertain that no solder paste is unintentionally jetted. In order to exemplify the difference between fast and slow, the fast movement could, for example, have a duration in the order of 10 microseconds, while the slow movement could have a duration in the order of a few milliseconds. According to yet another embodiment the plunger 21b is not retracted to the ready position after the last jetting has been performed, and before being relocated to the idle position, but is immediately moved into the idle position after the last jetting.

The time period during which the feed screw is rotated prior to the retraction of the plunger 21b from the idle position should not be excessive in order to minimise the amount of solder paste that is forced through the nozzle outlet 27. Ideally the residue is zero. On the other hand, said time period is variable and is determined as a function of the chosen feeding rate, i.e. the pulse frequency of the drive signal applied to

the stepper motor, and feeding pressure. By feeding pressure is meant the pressure at the outlet port 36. The feeding pressure in turn is related to the feeding rate. What is determinative for the feeding rate/pressure is 5 the desired jetting frequency and the droplet size of the jetting sequence to follow after the period of the idle state. The jetting frequency is adjustable as well.

Even though the present invention has been described above using exemplifying embodiments thereof, alterations, modifications, and combinations thereof, as understood by those skilled in the art, may be made without departing from the scope of the invention, which is defined in the accompanying claims.

CLAIMS

1. A method of jetting droplets of viscous medium onto a substrate, the method comprising the steps of:
  - 5 providing a jetting nozzle comprising a nozzle space and a nozzle outlet,
  - feeding said viscous medium into the nozzle space using feeding means,
  - 10 impacting said viscous medium using impacting means, thereby jetting viscous medium from the nozzle space in the form of droplets through the nozzle outlet towards the substrate,
  - wherein the step of feeding comprises
  - 15 prior to the jetting of each individual droplet, feeding a controlled amount of said viscous medium into the nozzle space, and
  - varying the controlled amounts of said viscous medium in dependence of the desired specific volume of each individual droplet.
- 20 2. The method as claimed in claim 1, wherein said step of feeding prior to the jetting of each individual droplet comprises:
  - 25 feeding viscous medium into the nozzle space such that the nozzle space is filled to a predetermined degree corresponding to a desired droplet volume of said individual droplet.
- 30 3. The method as claimed in claim 2, wherein said nozzle space is filled from the end opposite the nozzle outlet towards the end at the nozzle outlet, such that a portion of the nozzle space located closest to the nozzle outlet is free of viscous medium when the nozzle space is partially filled with an amount of viscous medium corresponding to a desired droplet volume.
- 35

4. The method as claimed in any one of the preceding claims, comprising the steps of:

- pausing the jetting operation,  
filling, during said pause and prior to jetting of  
5 the first droplet to be jetted after said pause, the  
nozzle space with viscous medium, and  
reducing, prior to said feeding of a controlled  
amount of viscous medium prior to said jetting of the  
first droplet, the amount of viscous medium in the nozzle  
10 space to a preset degree.

5. The method as claimed in claim 4, comprising the steps of:

- providing a chamber for containing viscous medium  
15 received from said feeding means, said chamber being  
located upstream of the nozzle space as seen in the  
feeding direction, and

providing said reduction of viscous medium in the  
nozzle space by increasing the volume of said chamber,  
20 such that a preset amount of viscous medium located in  
the nozzle space is retracted into said chamber.

6. The method as claimed in claim 5, wherein said impacting means comprises an impact end surface constituting a wall of said chamber, said wall being located opposite the nozzle space, further comprising the steps of:

- when pausing, moving said impacting means into an idle position, and  
30 providing said increase of the volume of said chamber by moving said impacting means, in a direction away from the nozzle space, from said idle position into a position ready for impacting.

35 7. The method as claimed in claim 6, wherein said moving of the impacting means into the idle position is

performed slowly such that no unintentional jetting of viscous medium is produced.

8. The method as claimed in any one of claims 4-7,  
5 wherein said filling during said pause comprises:  
filling said nozzle space by activating said feeding means for feeding viscous medium a predetermined time prior to said jetting of a first droplet.

10 9. The method as claimed in claim 8, wherein said filling during said pause comprises the step of:  
controlling the feeding operation of said feeding means and selecting said predetermined time such that a predetermined feeding pressure is obtained at an outlet  
15 end of said feeding means prior to said feeding of a controlled amount of viscous medium prior to said jetting of the first droplet.

10. The method as claimed in claim 9, wherein said  
20 step of controlling and selecting comprises the step of:  
controlling the feeding operation of said feeding means and selecting said predetermined time such that a flow of excess viscous medium out of the nozzle outlet, as a result of said filling of the nozzle space with  
25 viscous medium during said pause, is kept at a minimum.

11. The method as claimed in claim 9 or 10, wherein  
said filling during said pause comprises the step of:  
selecting said predetermined feeding pressure in  
30 adaptation to a desired jetting frequency of a jetting sequence following said pause.

12. The method as claimed in any one of the preceding claims, comprising the step of:  
35 removing viscous medium residue from the nozzle outlet.

13. The method as claimed in claim 12 when dependent on any one of claims 4-11, wherein said removing further comprises the step of:

removing excess viscous medium flowing out of the  
5 nozzle outlet as a result of said filling of the nozzle space with viscous medium during said pause.

14. The method as claimed in claim 12 or 13, wherein said removing comprises the step of:

10 providing a gaseous flow past the nozzle outlet such that the gaseous flow carries said viscous medium residue and excess viscous medium away from the nozzle outlet.

15. The method as claimed in claim 14, wherein said step of removing comprises the step of:

providing a suction generator for producing said gaseous flow.

16. The method as claimed in any one of the preceding 20 claims, comprising the step of:

providing said varying of the controlled amounts by regulating the feeding operation of said feeding means.

17. The method as claimed in claim 16, wherein said 25 regulation of the feeding operation comprises the step of:

regulating the feeding rate of said feeding means, such that the time for said feeding of a controlled amount of said viscous medium into the nozzle space is 30 substantially constant, regardless of the desired droplet volume.

18. The method as claimed in claim 16 or 17, wherein 35 said regulation of the feeding operation comprises the step of:

regulating the feeding rate of said feeding means, such that the time for said feeding of a controlled

amount of said viscous medium into the nozzle space is within a preset limit, thereby enabling the jetting frequency in a jetting sequence, that does not include pausing, to be substantially constant regardless of the 5 chosen jetting frequency or variations in the desired droplet volumes.

19. The method as claimed in claim 16, wherein said regulation of the feeding operation comprises the step 10 of:

regulating the duration of the feeding prior to the jetting of each individual droplet.

20. The method as claimed in any one of the preceding 15 claims, comprising the step of:

using a feed screw as said feeding means.

21. The method as claimed in any one of the preceding claims, wherein said impacting of jetting comprises the 20 step of:

regulating the impacting characteristics of said impacting means such that a desired exit velocity of each jetted droplet is obtained.

25 22. The method as claimed in claim 21, wherein said regulating of said impacting characteristics comprises:

regulating said impacting characteristics such that a predetermined exit velocity is maintained irrespective of the volume of the droplet to be jetted.

30 23. The method as claimed in claim 22, wherein said regulating of said impacting characteristics comprises the step of:

increasing the impact velocity for jetting a droplet 35 of a smaller volume and decreasing the impact velocity for jetting a droplet of larger volume, such that said predetermined exit velocity is maintained.

24. A device for jetting droplets of viscous medium onto a substrate, comprising:

5        a jetting nozzle from which the droplets of viscous medium are jetted, wherein the jetting nozzle comprises a nozzle outlet facing the substrate, and wherein the interior of the jetting nozzle defines a nozzle space arranged to receive viscous medium to be jetted;

10      feeding means for feeding viscous medium into said jetting nozzle; and

      impacting means for impacting said viscous medium, thereby producing jetting of viscous medium from the nozzle space in the form of droplets through the nozzle outlet towards the substrate;

15      wherein the device further comprises

      a control unit arranged for controlling said feeding means such that the amount of said viscous medium fed into the nozzle space for the subsequent jetting of droplets is varied in dependence of the desired specific

20      volume of each individual droplet.

25      25. The device as claimed in claim 24, wherein the feeding rate of said feeding means is adjustable, and

      wherein said control unit is arranged to control said feeding rate such that the time for said feeding of a controlled amount of said viscous medium into the nozzle space is substantially constant, regardless of the desired droplet volume.

30      26. The device as claimed in claim 24 or 25, comprising a feed screw as said feeding means.

27. The device as claimed in any one of claims 24-26, wherein the impacting characteristics of said impacting means are adjustable, and

5       wherein said control unit is arranged to control  
said impacting characteristics such that a desired exit  
velocity of each jetted droplet is obtained.

28. The device as claimed in any one of claims 24-27,  
further comprising a jetting chamber for receiving  
10      viscous medium, wherein said jetting chamber is in open  
communication with said nozzle space.

29. The device as claimed in claim 28, wherein the  
volume of said jetting chamber is increasable, such that  
15      upon increase of the volume of the chamber, an amount of  
viscous medium located in the nozzle space is withdrawn  
into said nozzle space.

30. The device as claimed in claim 29, wherein one  
20      wall of said jetting chamber opposite the nozzle space is  
constituted by an impact end surface of the impacting  
means,

25       wherein said impacting means is arranged to retract  
said impact end surface from the nozzle outlet such that  
said withdrawal of the viscous medium into the jetting  
chamber is achieved.

31. The device as claimed in claim 30, wherein said  
impacting means is arranged for impacting viscous medium  
30      in the jetting chamber with the impact end surface,  
thereby producing jetting of viscous medium from the  
nozzle space through the nozzle outlet towards the sub-  
strate.

35       32. The device as claimed in any one of claims 24-31,  
wherein said impacting means is a piezoelectric actuator.

33. The device as claimed in any one of claims 24-31, wherein said impacting means is a an actuator having electrostrictive, magnetostrictive, electromagnetic or shape memory alloy properties.

5

34. The device as claimed in any one of claims 24-33, further comprising a suction generator for producing a gaseous flow and directing means for directing said gaseous flow past the nozzle outlet.

10

## ABSTRACT

A method and a device for jetting droplets of viscous medium, such as solder paste, onto a substrate, such as an electronic circuit board. The volume of the droplets are adjusted by regulating the amount of viscous medium that is fed into a jetting nozzle for subsequent jetting of the viscous medium droplets therefrom. The exit velocity of the jettied droplets is adjusted or maintained substantially constant by regulating the velocity with which the viscous medium is impacted by impacting means. Furthermore, the rate at which viscous medium is fed by feeding means, such as a feed screw, into the nozzle is adjusted in order to regulate the feeding time required for feeding the viscous medium into the jetting nozzle, for instance in order to maintain a constant feeding time.

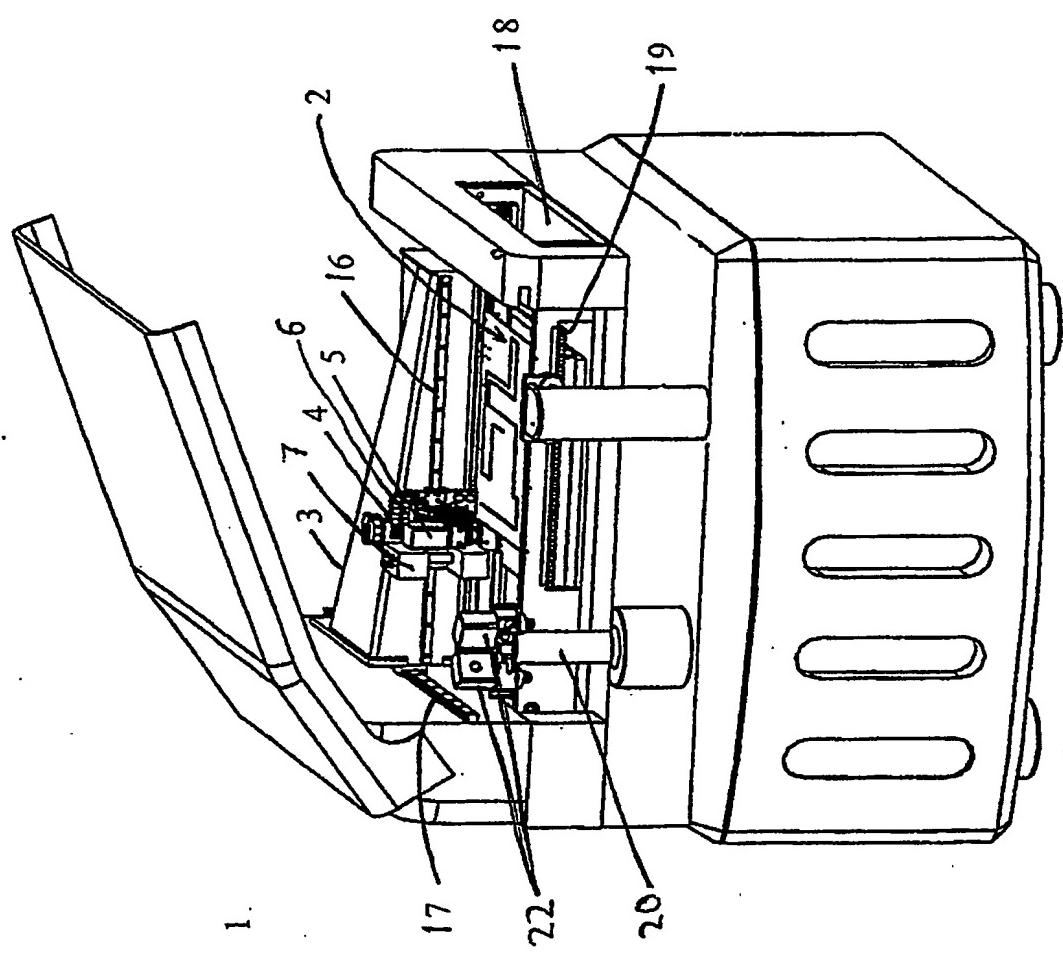


Fig. 1

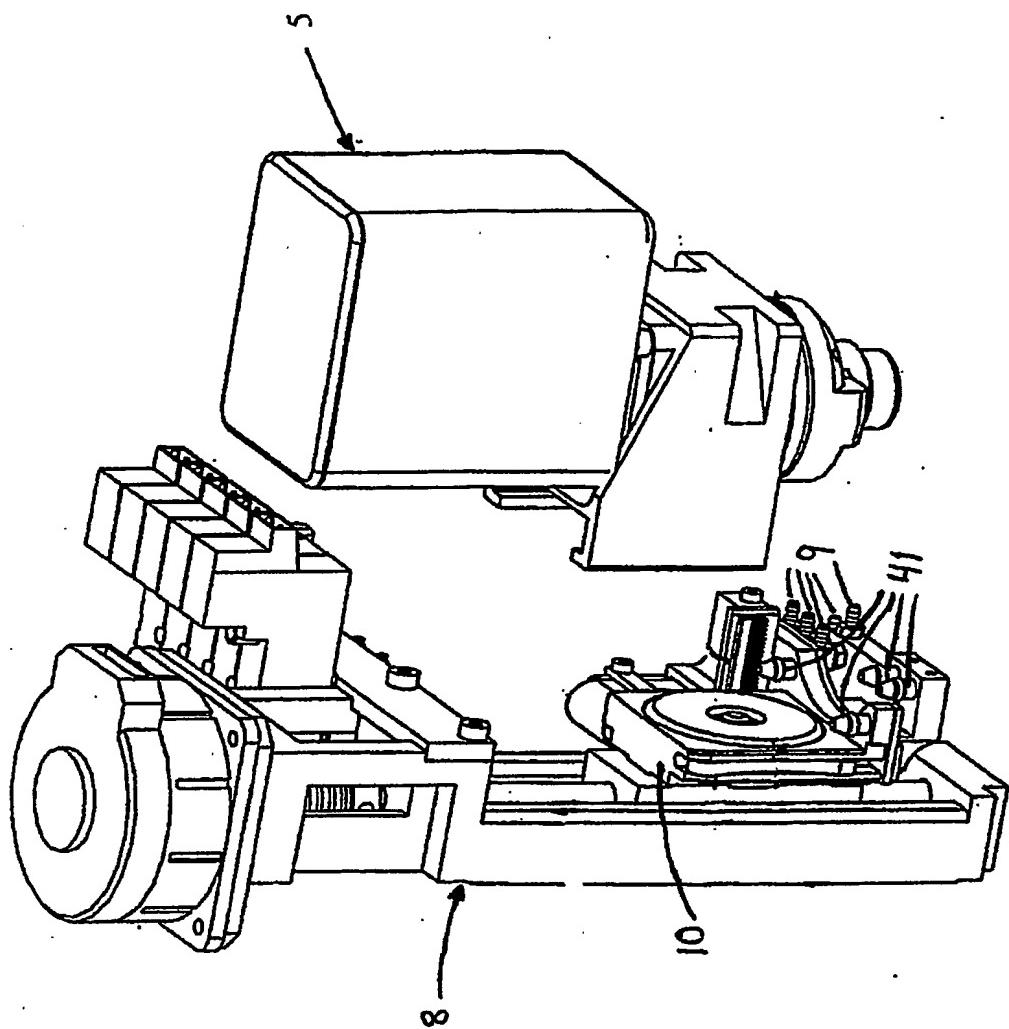


Fig. 2

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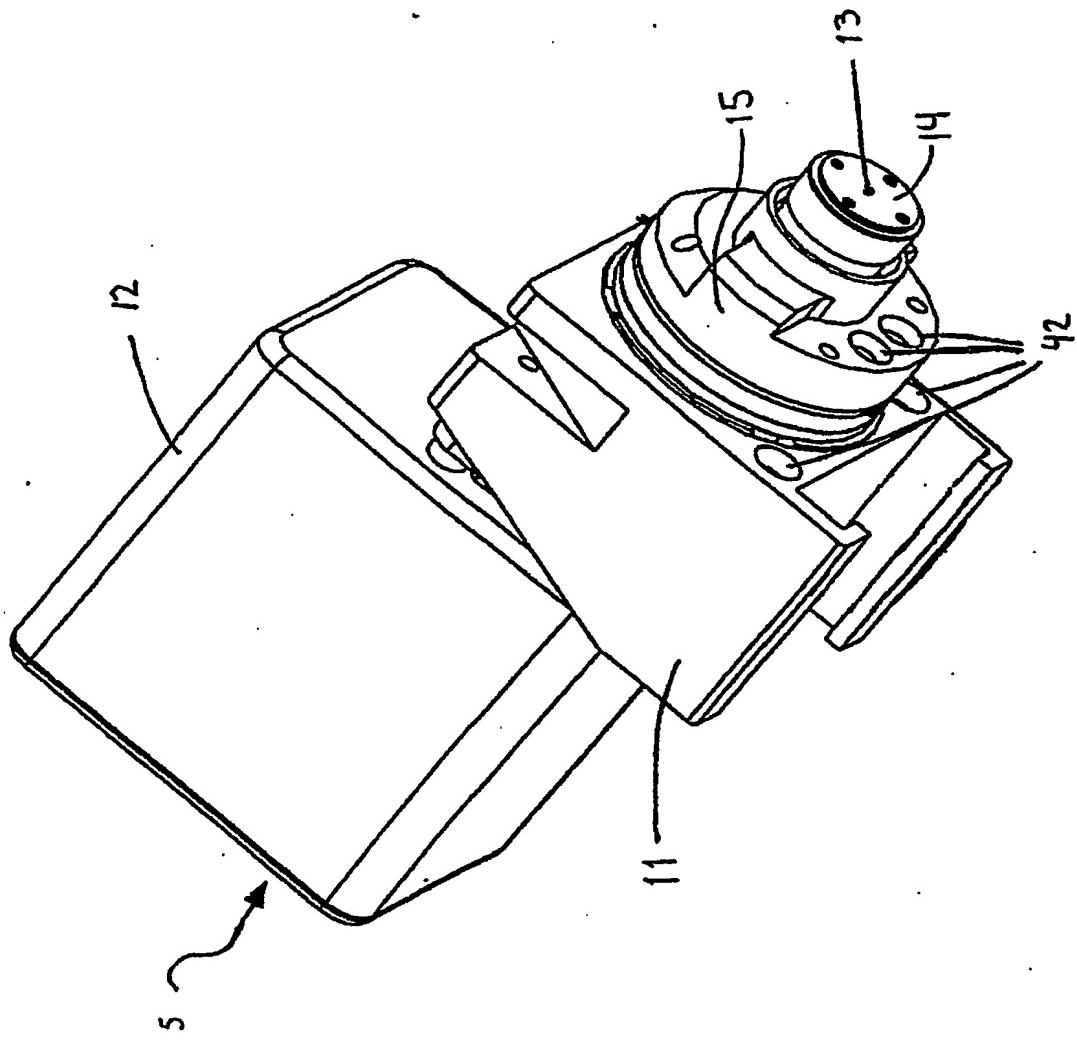


Fig. 3

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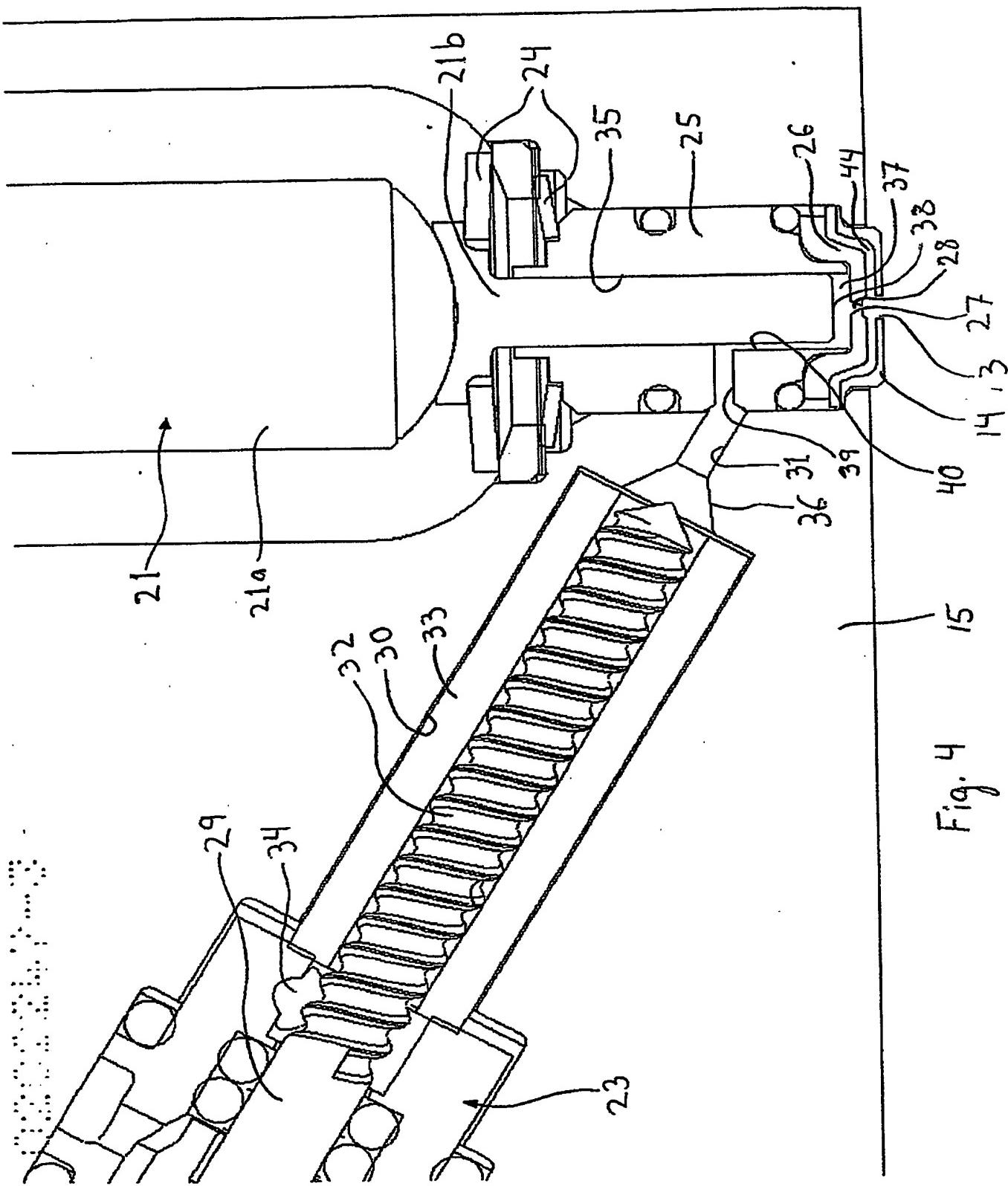


Fig. 4

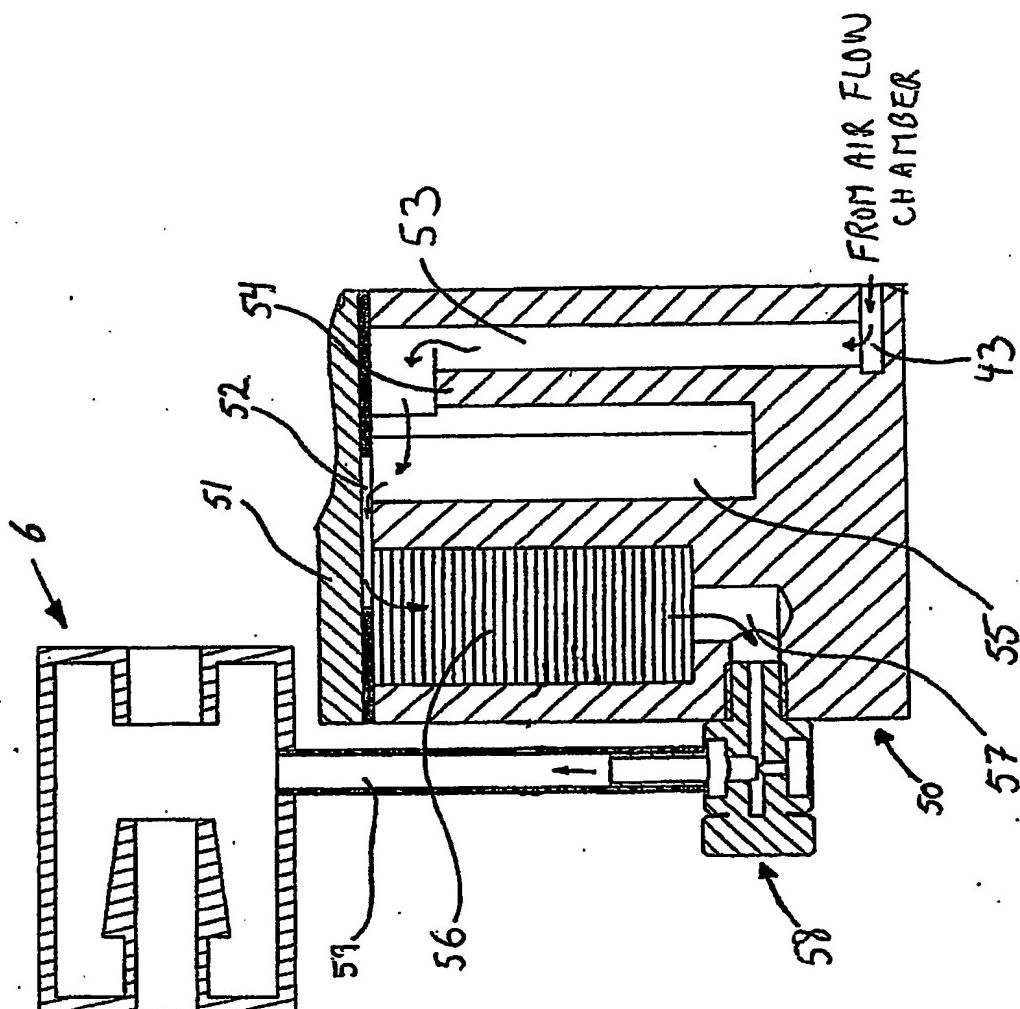


Fig. 5

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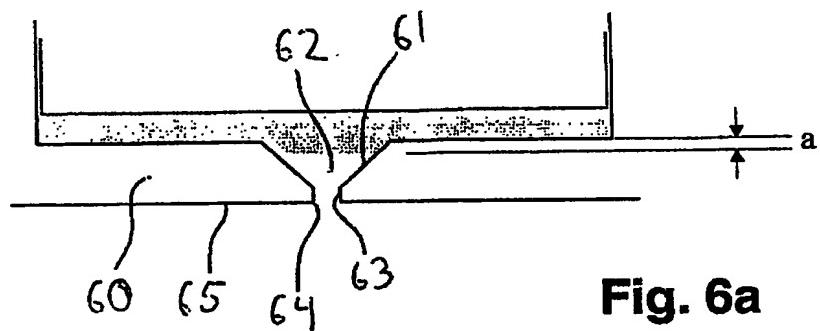


Fig. 6a

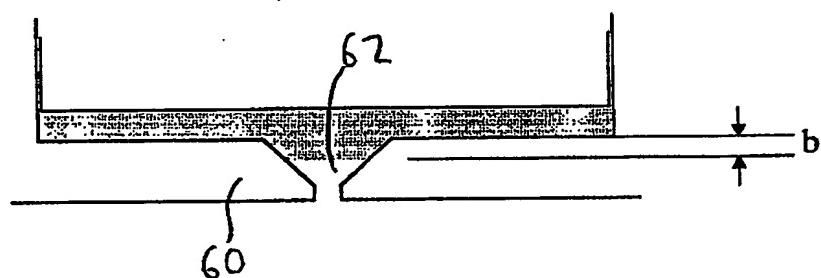


Fig. 6b

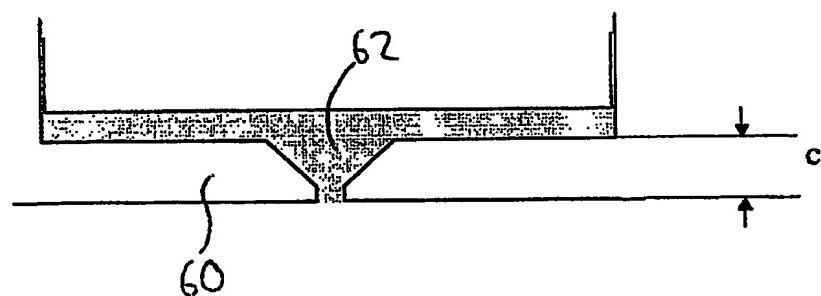


Fig. 6c

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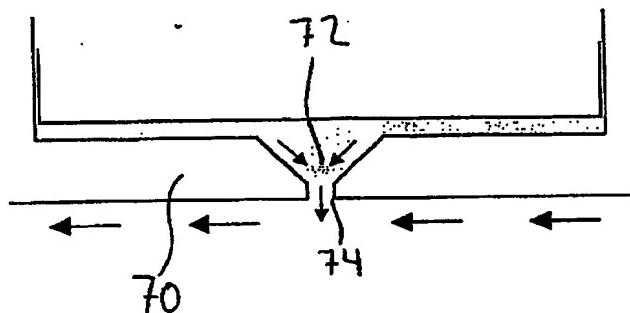


Fig. 7a

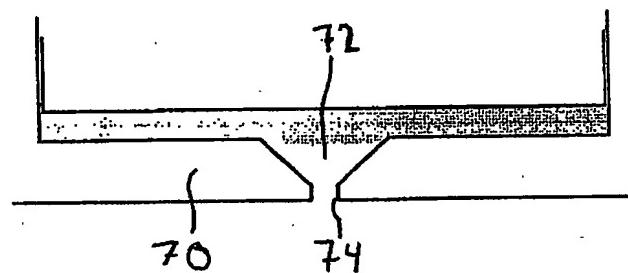


Fig. 7b

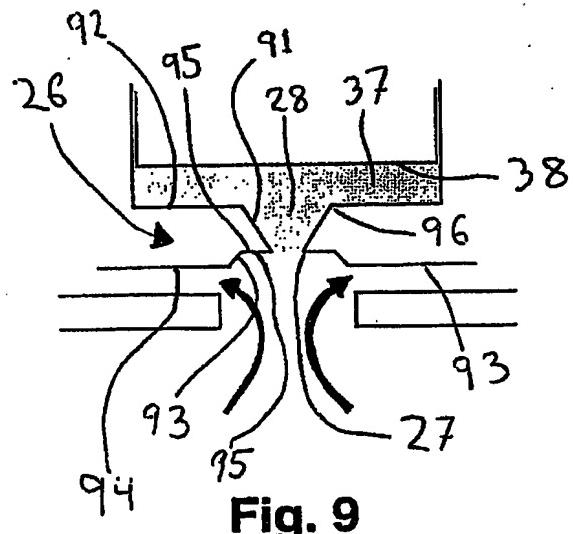
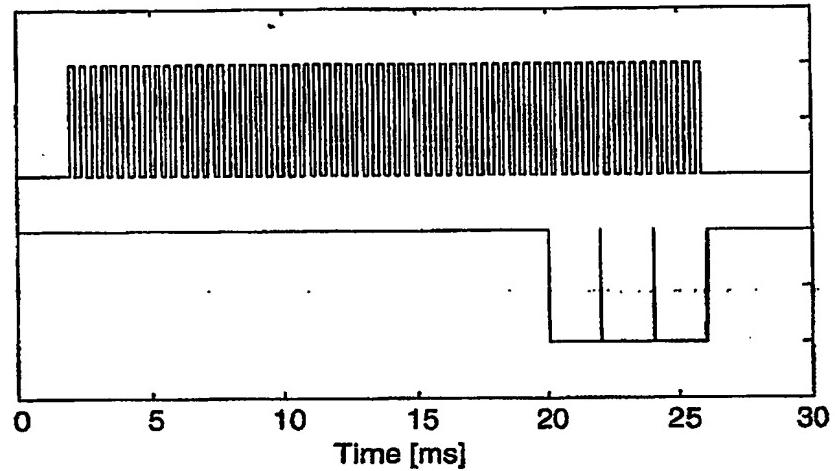
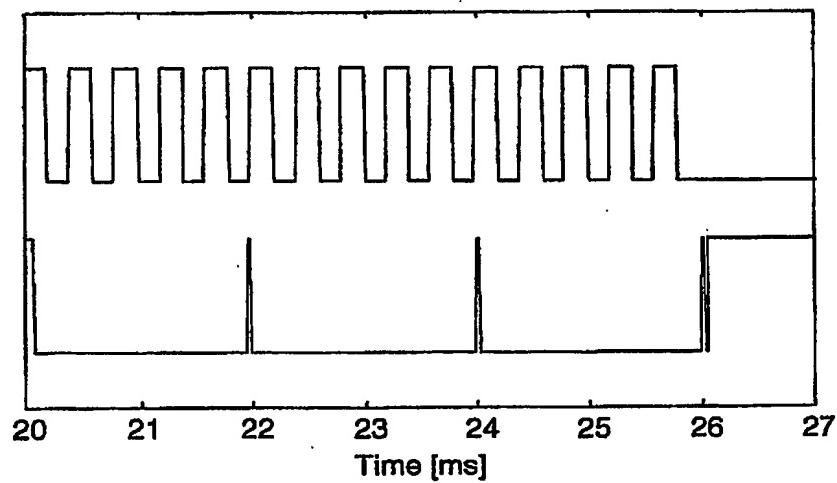


Fig. 9

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**Fig. 8a**



**Fig. 8b**

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